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Ejaculate Adjustment in Response to Sperm Competition Risk in Humans

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Abstract

Previous research suggests that human males, like males of many mammalian and avian species, adjust their ejaculate quality in accordance with sperm competition risk. Men who spend less time with their regular female partner since the couple's last copulation produce ejaculates with more sperm at the couple's next copulation (Baker & Bellis, 1993). We conducted a conceptual replication of this research to investigate whether sperm competition risk predicts ejaculate adjustment in human males using additional measures of sperm competition risk (e.g., perceptions of partner infidelity, presence of potential sexual rivals) and updated laser-optic semen analysis technology. We collected data from 34 heterosexual couples (age range: 18-32 years) from a university population who completed self-report surveys on their relationship dynamics and provided six ejaculate samples (3 copulatory, 3 masturbatory) across a 45-day period. Time spent together since the couple's last copulation was not associated with ejaculate quality. However, sperm concentration for copulatory ejaculates was higher for men who perceived more potential sexual rivals. Discussion situates the current results within the literature on human sperm competition and suggests several directions for future research.

Keywords: human sperm competition; ejaculate adjustment; ejaculate quality; evolutionary psychology

Ejaculate Adjustment in Response to Sperm Competition Risk in Humans

Sperm competition occurs when sperm from two or more males simultaneously occupy a female's reproductive tract and compete to fertilize ova (Parker, 1970). In species that practice social monogamy but also engage in extra-pair copulations, sperm competition can result in males unwittingly investing in offspring to whom they are not genetically related (i.e., cuckoldry; Parker, 1970). Sperm competition is known to occur – or has been inferred to occur – in many species, including humans (e.g., Baker & Bellis, 1993, 1995; Birkhead & Møller, 1998; Gomendio & Roldan, 1991; Parker, 1970; Smith, 1984). Non-paternity, or instances in which the social father is genetically unrelated to his putative offspring, provides evidence of sperm competition in humans. Scelza et al. (2020) found that 48% of children in a sample of the indigenous Himba in northern Namibia were genetically unrelated to their social father. It is worth noting, however, that rates of non-paternity that are this high are not typical; the Himba place a high importance on social fatherhood and the stigma associated with women having extra-pair partners is lower than in other societies (Scelza et al., 2020). Research with Western samples suggests much lower (but non-zero) rates of non-paternity in humans. For example, a meta-analysis reported a non-paternity rate of 3.1% across 32 studies (Voracek et al., 2008). Investigations of relative testis size (i.e., testis mass relative to body mass) provide additional insight into ancestral levels of sperm competition in humans, as relative testis size is positively correlated with sperm competition intensity across primate species (Baker & Shackelford, 2018; Simmons & Fitzpatrick, 2012). Although relative testis size in humans is smaller than in highly polyandrous primates, it is larger than in more monogamous primates (Short, 1981), suggesting moderate levels of sperm competition over human evolutionary history.

To avoid the costs of cuckoldry even under conditions of moderate sperm competition, human males may deploy anti-cuckoldry tactics, such as engaging in more mate retention behaviors (Buss & Shackelford, 1997; Goetz et al., 2005; Starratt et al., 2007) and/or more frequent copulation after spending longer periods of time apart from their partner (Shackelford et al., 2002). Anti-cuckoldry tactics also include the production of a high-quality ejaculate (Kilgallon & Simmons, 2005; Shackelford et al., 2006; Simmons & Fitzpatrick, 2012), such that higher male sexual arousal (and duration of arousal) during copulation and consequently higher-quality ejaculates increase the likelihood of success in sperm competition if the partner has been (or may soon be) sexually unfaithful (Goetz et al., 2005; Pound et al., 2002). Despite critics arguing that declining ejaculate quality across the past several decades is evidence against sperm competition in humans (Levine et al., 2023; reviewed by Pham & Shackelford, 2014), there is evidence that human males adjust their ejaculate quality as a function of sperm competition risk.

In a landmark study, Baker and Bellis (1993) provided evidence for ejaculate adjustment in humans, showing that men produce more sperm in ejaculates when they have spent less time together with their partner since the couple's last copulation. Baker and Bellis considered time spent apart (during which the man cannot account for his partner's activities) as an objective indicator of sperm competition risk and concluded that human males engage in ejaculate adjustment in response to sperm competition cues. In other words, the more time men spend with their female partners, the lower the risk of sperm competition. Indeed, previous work has shown that men are motivated to perform various forms of mate guarding, which include efforts to directly control or account for the female partner's whereabouts, especially when the risk of sperm competition is higher (Goetz et al., 2005; Shackelford et al., 2006). Additionally, men who spend a greater proportion of time apart from their partner report greater interest in copulating

with her and perceive that she is more sexually attractive (Shackelford et al., 2002). Thus, if men do adjust their ejaculate quality, time spent apart from their partner may be a cue of sperm competition risk that regulates ejaculate adjustment.

No other researchers besides Baker and Bellis (1993) have investigated ejaculate adjustment as a sperm competition tactic in humans (although these researchers reported similar results in updated analyses with additional participants; Baker, 1997; Baker & Bellis, 1995). Furthermore, Baker and Bellis's research included only one measure of sperm competition risk – time spent together since the couple's last copulation. On the one hand, greater time apart since last copulation does indicate greater risk of sperm competition, as time apart is time during which the woman is more likely by her own reports to engage in extra-pair copulation (Baker & Bellis, 1989). On the other hand, time spent together since the couple's last copulation may not provide a robust assessment of a man's risk of sperm competition, given the range of activities the female partner could engage in during the man's absence (e.g., working a shift at her job, running errands, spending time with other women). Other potential risk factors for sperm competition in humans include a partner's previous infidelity (a robust predictor of future partner infidelity; Knopp et al., 2017) and the presence of potential sexual rivals (e.g., the female partner's number of male friends and co-workers; Pham & Shackelford, 2013). Thus, time spent apart from her partner may not be sufficient to arouse his suspicions of her infidelity. In contrast, a woman with a history of infidelity and/or many male friends with whom she spends time during her regular partner's absence represents a greater infidelity risk and, therefore, a greater sperm competition risk (Knopp et al., 2017).

The current study aimed to replicate and extend the work of Baker and Bellis (1993; see also Baker, 1997; Baker & Bellis, 1995), and to address limitations in the literature concerning

ejaculate adjustment in response to sperm competition risk in humans. We collected data from a sample of 34 heterosexual couples and, longitudinally, over a 45-day period during which multiple ejaculate samples were collected per couple, investigated the associations that risk factors for sperm competition had with ejaculate quality. Specifically, we measured (1) time spent together since the couple's last copulation, (2) male perceptions of female infidelity, and (3) male perceptions of the presence of potential sexual rivals. We also used more advanced methods of measuring ejaculate quality and controlled for relevant covariates known to affect ejaculate quality, such as the number of days of abstinence before ejaculate sample production (see "Covariates" section, below).

Method

Participants and procedures

A total of 58 heterosexual couples were recruited for this study. After accommodating for attrition (24 couples did not complete all seven sessions), the final sample comprised 34 couples, at least one member of which attended a Midwestern university in the United States that housed the researchers, with couples' ages ranging from 18 to 32 years (M = 21.55; SD = 3.55). The majority (72.2%) of the sample was Caucasian (14.8% was African American, with 13% "other" or did not report). By self-report, male participants had not had a vasectomy or sought infertility treatment, and female participants were not using any hormonal contraceptive at the time of data collection. All couples had to be between the ages of 18 and 35 years to control for age-related fertility decline (Dunson et al., 2004) and were currently in a committed, heterosexual, sexually active relationship that had been ongoing for at least three months (range = 3-146 months; M = 26.17 months; SD = 27.08).

All procedures were approved by the Institutional Review Board of the university where data were collected. Couples were recruited between 2016 and 2022 (with a break in data collection during 2020-2021 due to the COVID-19 pandemic) via advertisements posted on bulletin boards around campus. Participants contacted the laboratory to schedule a total of seven in-person sessions. In the first session, couples were separated and each member was escorted to a private room to complete several self-report questionnaires, including several related to sperm competition risk (e.g., time spent together since last copulation, perceptions of partner infidelity, presence of potential sexual rivals) and several not relevant to the current analyses (e.g., personality traits). Then, researchers secured several anthropometric measurements for each member of the couple while separated in different rooms, including shoulder, waist, and hip circumference, height, and weight. After the first session, participants received materials required to collect and transport ejaculates across six return sessions within a 45-day period, including three copulatory samples and three masturbatory samples (couples were permitted to select at which sessions they delivered the copulatory and masturbatory samples). Couples were instructed to not schedule return sessions while the female partner was menstruating. The materials included a non-latex, non-spermicidal condom (SKYN brand; Iselin, NJ, USA), plastic twist-tie, screw-top specimen container, biohazard Ziploc bag, and aluminum foil (see Figure 1).

Following World Health Organization (2010) guidelines, male participants were instructed to abstain from ejaculating for at least 48 hours (but no longer than seven days) before each session. For masturbatory sessions, male participants were asked to masturbate without the help of their partner or the use of any materials such as pornography or lubricant that we did not provide. Another part of the masturbatory sessions involved asking participants to smell male body odor scents collected from t-shirts both prior to and during masturbating as part of another

project (the details of which will be outlined elsewhere). Participants masturbated to ejaculation into a specimen container in a private location of their choosing. After ejaculation, participants sealed the specimen container, placed the specimen container into the plastic biohazard bag, and wrapped the container in aluminum foil. The aluminum foil was used to keep the sample warm as a means of minimizing sperm death. In addition to the use of aluminum foil, participants were instructed to keep the sample warm by transporting it under their arm and deliver it to the laboratory within one hour of ejaculation (as a notable percentage of sperm die after this period when outside the body).

For copulatory sessions, participants were asked to copulate with their regular partner in a private location of their choosing and to ejaculate while the penis was in the vagina and while wearing the provided condom. After ejaculation, participants sealed the condom with the plastic twist-tie, placed it in a specimen container, wrapped the container in aluminum foil, transported it under their arm, and delivered it to the laboratory within one hour of ejaculation. Across both types of ejaculate samples (masturbatory and copulatory), the mean amount of time elapsed between the production of the ejaculate and its arrival to the lab was approximately 37 minutes. However, we note that in intrauterine insemination research, there were no significant differences in sperm concentration, motility, or morphology between ejaculate sample types analyzed less than 21 minutes after ejaculation versus more than 107 minutes after ejaculation, although conception likelihood was higher for the younger samples than for the older samples (Punjabi et al., 2021). Although the researchers originally planned for male participants to wear condoms in both the masturbatory and copulatory sessions, some participants reported difficulty maintaining erections when masturbating while wearing a condom, and so participants were

permitted to ejaculate directly into the specimen container. All participants provided written consent and each couple received a total of US$210 for their participation.

Measures

Time spent together since couple's last copulation. Following Baker and Bellis (1993), participants reported the number of hours since their last copulation and how many of those hours (since their last copulation) they spent together (including sleeping time) at all seven sessions.

Men's perceptions of partner infidelity. We assessed men's perceptions of partner infidelity by averaging Likert scale responses (ranging from 1 to 7, where 1 = *not at all likely/strongly disagree* and 7 = *extremely likely/strongly agree*) across the following four items: "What is the likelihood that your current partner has been unfaithful to you in the past?", "How much do you agree or disagree with the following statement: My current partner has probably been with someone else sexually during our relationship?", "How likely do you think it is that your current partner will in the future have sexual intercourse with someone other than you, while in a relationship with you?", and "Please indicate your agreement or disagreement with the following statement: My partner will probably be sexually unfaithful to me in the future." The alpha reliability for this composite measure was 0.82.

Men's perceptions of potential sexual rivals. Men completed a brief survey about their perceptions of the number of potential sexual rivals. From responses to this survey, we created composite variables for *the number of sexual rivals* and *the amount of time spent with sexual rivals*. For the number of sexual rivals, men answered the following two items: "How many male friends does your partner currently have?" and "How many male coworkers does your partner currently have?" The response option was left open-ended so that men could type in the

appropriate number. Then, we summed the number of male friends and male coworkers together to create the number of sexual rivals composite variable ($\alpha = 0.73$). For the amount of time spent with sexual rivals, men answered these two items: "How much time does your partner spend with her male friends?" and "How much time does your partner spend with her male coworkers?" Response options to both questions were based on a Likert-type scale ranging from 1 (*very little*) to 10 (*very much*). For the composite variable of amount of time spent with sexual rivals, we averaged the responses from these two items ($\alpha = 0.50$).

Ejaculate quality. Ejaculate quality was assessed using the Semen Quality Analyzer Gold version (SQA-V; Medical Electronic Systems, Los Angeles, California, US), a fully automated machine that analyzes ejaculates along several clinical measures (see Pham et al., 2018, for details) and has previously demonstrated greater precision than both manual analysis and Computer Assisted Semen Analysis (CASA; Lammers et al., 2014). Couples produced six ejaculate samples across a 45-day period (three via masturbation and three via copulation; see Procedures above). Upon arrival to the lab, a researcher pipetted (with an Ashton pump pipette) the entire ejaculate from the specimen container and measured the volume of the ejaculate (in milliliters [mL]) using the volumetric markings on the pipette and then transferred the ejaculate back into the specimen container. A test strip (Medical Electronic Systems, Los Angeles, California, US) was then dipped for two minutes into the ejaculate to assess pH and white blood cell count. Then, 0.5 milliliters of each ejaculate was syringed into a proprietary measurement capillary (Medical Electronic Systems, Los Angeles, California, US), which was inserted into a chamber in the SQA-V for automatic analysis using electro-optical technology, signal conversion, and the application of proprietary algorithms. After completion of the two-minute automated analysis, all materials that directly contacted the ejaculate were discarded in a

biohazard waste container. The SQA-V estimates 17 ejaculate parameters (see Pham et al., 2018). Because Baker and Bellis (1993) measured the number of sperm in an ejaculate, we focused on the parameter of sperm count. Additionally, because human sperm competition research historically has focused on sperm motility, concentration, and count (Baker & Bellis, 1993; Kilgallon & Simmons, 2005), we included the parameters of rapid progressive motile sperm concentration and overall sperm concentration (measured in millions per milliliter).

Covariates. Some ejaculate parameters vary over the lifespan—for example, the number of sperm in an ejaculate decreases with age (Cooper et al., 2010; Ng et al., 2004). Additionally, obesity is linked to infertility in men, with Body Mass Index (BMI) being negatively associated with sperm count (Eisenberg et al., 2013). Moreover, some ejaculate parameters are affected by abstinence duration before ejaculation; for example, rapid and repeated ejaculation reduces sperm number in subsequent ejaculates (Hopkins et al., 2017). Lifestyle factors, such as using a heated driver's seat, also reduce ejaculate quality (Kilgallon & Simmons, 2005). Relationship length is also relevant as men (and males of other species) have been documented to experience sexual habituation to a familiar partner (i.e., the Coolidge effect; Hughes et al., 2021; Joseph et al., 2015). Thus, we assessed several covariates known to affect ejaculate quality, including age (in years), BMI, abstinence duration (in days), relationship length, and lifestyle factors (e.g., using hot saunas). To assess lifestyle factors, we administered the Lifestyle Factors Questionnaire (Kilgallon & Simmons, 2005), which includes three questions: "Do you use your laptop on your lap?", "Do you use a heated driver's seat?" "Do you use hot baths and sauna?" Response options for the questions were dichotomous in the form of 1 = yes and 0 = no. We calculated a single score for lifestyle factors by summing responses to the three questions, such that higher numbers indicated more sperm-damaging habits and lower numbers indicated fewer

sperm-damaging habits across the six return sessions. It should also be noted that the anonymous datasets with these data are available in the Supplemental Materials section.

Results

Multilevel models were used to examine whether indicators of sperm competition risk were associated with ejaculate quality. The data constituted a multilevel data structure because observations at one level of analysis were nested within another level of analysis (i.e., each participant provided several masturbatory and copulatory ejaculates over time; Bryk & Raudenbush, 1992, 1998; Raudenbush & Bryk, 2002). To account for violation of the independence assumption that occurs with a nested data structure, we conducted separate multilevel models for each of the three indicators of ejaculate quality (i.e., concentration of rapid progressive motile sperm, number of motile sperm, and sperm concentration). Each of these models included predictors at Level 1 (*within-person level*; i.e., time spent together since the couple's last copulation, type of sample [masturbatory vs. copulatory], abstinence duration, and lifestyle factors) and Level 2 (*between-person level*; i.e., perception of female infidelity risk, number of potential male sexual rivals, time female partner spent with potential male sexual rivals, male age, male BMI, and relationship length).

The Level 1 predictors—with the exception of sample type (i.e., masturbatory vs. copulatory)—were *person-mean-centered* due to their variability within the same participant between sessions (e.g., participants may spend more time with their partner since their last copulation for some sessions than for other sessions) and across participants (e.g., some participants may spend more time with their partner since their last copulation than other participants). Person-mean-centering reduces the influence of habituation and adjusts for possible self-report biases. The use of person-mean-centering for the Level 1 variables allowed

us to examine the associations that deviations from normal experiences of the participant had with ejaculate quality (e.g., do participants produce higher quality ejaculates when they spend less time with their partner since the last copulation *than is typical for them*?).

Concentration of rapid progressive motile sperm

There was no association between the time that men spent together with their partner since the couple's last copulation and the concentration of rapid progressive motile sperm across masturbatory and copulatory samples ($B = 0.00$, $SE = 0.03$, $t = 0.00$, $p = .997$). However, significant associations emerged for men's perceptions of their partner's infidelity ($B = -1.35$, $SE = 0.57$, $t = -2.35$, $p = .024$), lifestyle factors ($B = -3.63$, $SE = 1.44$, $t = -2.52$, $p = .013$), and ejaculatory sample type (masturbatory vs. copulatory; $B = -4.97$, $SE = 0.78$, $t = -6.39$, $p < .001$). These results showed that men produced ejaculates with a higher concentration of rapid progressive motile sperm when they perceived their partners to be more faithful, reported fewer lifestyle factors associated with lower ejaculate quality, and provided masturbatory (vs. copulatory) samples. No other associations or cross-level interactions emerged from this analysis.

Number of motile sperm

There was no association between the time that men spent together with their partner since the couple's last copulation and the number of motile sperm ($B = 0.07$, $SE = 0.13$, $t = 0.60$, $p = .550$). However, significant associations emerged for men's age ($B = 4.42$, $SE = 1.53$, $t = 2.88$, $p = .007$) and the duration of abstinence prior to ejaculate production ($B = 6.02$, $SE = 2.95$, $t = 2.04$, $p = .042$). These results showed that men who are older and had longer periods of abstinence produced ejaculates with more motile sperm. No other associations or cross-level interactions emerged from this analysis.

Sperm concentration

There was no association between the time that men spent together with their partner since the couple's last copulation and sperm concentration ($B = 0.17$, $SE = 0.15$, $t = 1.12$, $p = .264$). However, significant associations emerged for the number of potential male sexual rivals ($B = 1.76$, $SE = 0.87$, $t = 2.02$, $p = .050$) and ejaculate sample type (masturbatory vs. copulatory; $B = 25.39$, $SE = 2.99$, $t = 8.49$, $p < .001$). These results showed that men produced ejaculates with a higher sperm concentration when they provided copulatory samples, and when they reported that their partner interacted with more potential sexual rivals. No other associations or cross-level interactions emerged from this analysis, including those related to time spent with potential male rivals (i.e., it was only the *number* of potential male rivals – not the *time spent with* male rivals – that was significantly associated with sperm concentration).

Discussion

Baker and Bellis (1993) reported that men produced more sperm during copulation when they had spent less time together with their partner since the couple's last copulation. The results of the current study differ from several of the results reported by Baker and Bellis. Most importantly, time spent together since the couple's last copulation was not associated with any of the several indicators of ejaculate quality in the present study. However, it is important to note that the copulatory ejaculates produced by men had higher sperm concentrations than their masturbatory ejaculates. Several other indicators of sperm competition risk that we assessed – and which were not assessed by Baker and Bellis – did yield results consistent with ejaculate adjustment in response to sperm competition risk. Participants produced ejaculates with greater sperm concentration when they perceived that their partner interacted with more potential sexual rivals (as assessed at the first session). That is, men produced ejaculates with a higher

concentration of sperm (assessed across sessions) when they also perceived that their partner had more male friends and coworkers (i.e., potential sexual rivals). This finding is consistent with sperm competition theory applied to humans.

There were also several results not directly related to sperm competition risk. Specifically, concentration of rapid progressive motile sperm was higher in masturbatory than in copulatory ejaculates, and also was higher when men engaged in fewer lifestyle habits related to lower ejaculate quality (e.g., putting a laptop in one's lap; see also Kilgallon & Simmons, 2005). Although the latter result is not surprising, we did not expect the concentration of rapid progressive motile sperm to be higher in masturbatory than in copulatory samples, given previous research suggesting higher ejaculate quality (likely as a function of greater arousal before ejaculation) for copulatory samples (Sofikitis & Miyagawa, 1993; Zarmakoupis-Zavos et al., 1999). It is particularly counterintuitive that overall sperm concentration was higher in copulatory samples despite these samples having a lower concentration of rapid progressive motile sperm. One possibility is that couples may have delivered masturbatory samples to the laboratory more quickly following ejaculation than copulatory samples, given that copulatory samples also may have included more post-intercourse activities (e.g., putting clothes on, washing up, cuddling). Such post-intercourse activities may have delayed delivery of copulatory samples, resulting in reduced ejaculate quality relative to masturbatory samples. Another possibility is that exposure to the male scents in the masturbatory sessions could account for the higher concentration of rapid progressive motile sperm in the masturbatory samples. Perhaps male scents serve as a stronger cue of sperm competition compared to other cues, such as time spent apart. Also, the number of motile sperm was greater for older participants (although we note that the range of ages was limited in the current sample) and those who reported a greater

abstinence duration prior to ejaculate production. It is possible that the number of motile sperm was lower for younger participants due to unmeasured lifestyle factors. For example, younger people are more likely to vape or consume marijuana (e. g. Lewis et al., 2022), both of which are associated with lower ejaculate quality (Gunderson et al., 2015; Nahak & Pramesemara, 2023). Because these results are not related directly to sperm competition, they are not our focus here, but we do recommend that future research investigates these and other sources of variation in ejaculate quality.

Of note, one of the current results directly contradicted a prediction of sperm competition theory. That is, men produced higher concentrations of rapid progressive motile sperm when they perceived their partner to be *more faithful*. Sperm competition theory predicts that men will expend more metabolic energy producing high-quality ejaculates (including those with a high concentration of rapid progressive motile sperm) when their partner is *less faithful.* Contrary to predictions generated by sperm competition theory, results of the present study suggest that ejaculate adjustments may function to increase the likelihood of impregnating *more* faithful women (perhaps through greater arousal with women perceived as faithful). One potential explanation for this result may be that ejaculate adjustment operates differently in men pursuing a more long-term (versus short-term) mating strategy. Indeed, comparative primate literature suggests that ejaculate adjustment is designed to increase fertilization success in highly promiscuous species (Harcourt et al., 1995; Møller, 1988); however, mating practices vary more widely in humans than in other primate species when considering differences in sociosexuality (Schmitt, 2005) and within-species differences in life history strategy (and how life history strategy relates to ejaculate quality; Barbaro et al., 2019). Further, direct comparisons of ejaculate quality between men who frequently engage in short-term casual sex and men who

pursue long-term mating arrangements have not been conducted, so it is possible that mechanisms related to sperm competition are more complex in humans than in other species. Although human sperm competition may occur primarily in the context of long-term relationships (Shackelford et al., 2002), future research might directly examine differences in ejaculate quality as a function of the mating context (e.g., short-term versus long-term relationships). Finally, it is possible that this counterintuitive finding is, at least in part, the result of sampling bias. That is, couples included in our final sample were required to coordinate and attend 7 in-person lab sessions with their romantic partner, and in this sample, men's perceptions of their partner's faithfulness were quite high (M = 1.65; lower scores indicating higher perceived faithfulness). Thus, the design of the present study may have resulted in a final sample of couples that was, on average, highly committed and faithful to their relationships. As discussed previously, ejaculate adjustment may operate differently in men oriented toward a more long-term mating strategy, and such men may have been overrepresented in the present study.

There are several possible reasons why the results of the current research differ from those of Baker and Bellis (1993). It could be that ejaculate adjustment by human males simply does not occur in the way that Baker and Bellis describe. There are, however, several other explanations to consider. For instance, it may be that the periods of time spent apart since the couple's last copulation observed in the current research were not sufficient to activate ejaculate adjustment mechanisms. The average duration of time between copulations was about four days in the current research, with couples, on average, spending half of that period of time together. The results therefore may reflect a restriction-of-range-effect with regard to the duration of time that couples spent together since their last copulation. An additional concern with using

proportion of time apart as an indication of sperm competition risk is whether men's efforts to mitigate this risk are equally effective after considerable periods of separation (e.g., military service members returning from international deployment; Knobloch & Theiss, 2012). Indeed, efforts to adjust ejaculate quality may be inconsequential if the female partner's egg has already been fertilized via extra-pair copulation. However, short of confirmed infidelity and subsequent fertilization, an evolutionary perspective predicts that ejaculate adjustment will follow periods of separation, as the evolved mechanisms regulating ejaculate quality should be attuned to cues of sperm competition risk (e.g., time spent apart) rather than ancestrally unknowable variables such as the partner's fertilization status.

Another factor to consider is the nature of the mechanism by which time spent apart—or other indicators of sperm competition risk—might affect ejaculate quality. For example, does sperm competition risk affect the *production* of sperm (i.e., spermatogenesis)? If so, then the timing of exposure to sperm competition risk, as well as the chronic nature of this risk, may be important because men produce several million sperm per day, but the entire process of spermatogenesis requires approximately 64 days (e.g., do men who are exposed to sperm competition risk produce higher-quality ejaculates two months later?). Alternatively, sperm competition risk may affect the *release* of sperm rather than their production. If this is the case, then this would allow ejaculate adjustments to be made more readily in response to current levels of sperm competition risk. However, such processes have not been explored in humans, so it is unknown whether indicators of sperm competition risk affect the production and/or the release of sperm.

The pattern of current results may be consistent with the controversial proposal of sperm heteromorphism (see Birkhead, 2000), which suggests that not all sperm are designed to fertilize

the egg, but instead that some sperm may have other functions (e.g., forming copulatory plugs; Baker & Bellis, 1988; Kura & Nakashima, 2000; Ramm et al., 2005). In the current research, the finding that greater number of perceived potential sexual rivals is associated with production of ejaculates with higher sperm concentration (and thus presumably less seminal fluid) might suggest that these additional sperm could perform other functions, such as serving a defensive role, including contributing to buildup of dead sperm to block the path for sperm of rival males (Althaus et al., 2010; Schneider et al., 2016). Perhaps seeing these male rivals in the same social situations as their regular partner cues men to produce these competitive ejaculates with greater sperm concentration. Further, the finding that rapid progressive motile sperm increases when men perceive their partner to be more faithful suggests that, when men perceive lower risk of sperm competition, ejaculate adjustment mechanisms may prioritize the production of "egg-getter" sperm (i.e., sperm with rapid progressive motility). When sperm competition risk is lower, there is less need for higher sperm concentration, which may include non-progressively motile sperm (i.e., sperm that might perform other functions related to sperm competition). Future research should investigate this further and consider other possible psychological sources of variation in sperm quality, such as pregnancy ambivalence or the desire to become a father.

A limitation of the current research is that female participants were not asked to report on how they spent their time apart from their regular male partner. Such information may be important for understanding how couples' time spent apart could affect ejaculate quality. For instance, if the female partner spends most of her time at home doing housework while her regular partner is away, then there would be fewer subtle cues to sperm competition for her partner to observe, and thus, would be expected to have no or minimal effect on ejaculate quality. However, if the female partner spends more of this time apart with attractive potential

sexual rivals to her regular partner, then subtle correlates of these activities may be present for her regular partner to observe (e.g., slight changes in the woman's behavior after spending time with other men) that could affect her partner's ejaculate quality at the couple's next copulation. In other words, men may require multiple cues to sperm competition risk rather than just a single cue, and/or the cues most directly related to female sexual activity with other men may have a larger effect on ejaculate quality. In this case, perceived higher number of rival males may present as a stronger indicator of sperm competition risk than simply the amount of time the couple spends apart since their last copulation. Moreover, it is possible that male friends and male coworkers are not equally compelling sperm competition threats, with perhaps male friends perceived as more compelling threats than male coworkers. A related point is that time spent apart may not be as robust a cue of sperm competition today than it was in the early 1990s when Baker and Bellis (1993) conducted their research. For example, increased communication between couples via texting and smart phones may facilitate more accurate monitoring of a partner's whereabouts and activity. Additionally, the increased prevalence of consensual extra-pair sexual behavior (e.g., "open" relationships; Fairbrother et al., 2019; Mogilski et al., 2020) may have had unexpected effects on the results of the present study and could be considered in future research.

Another limitation of this study was the small sample of 34 couples that provided complete data. This is an important limitation because small sample size increases the risk of both Type I and Type II errors. However, Baker and Bellis (1993) had a similar sample size of 35 couples, and not all of those 35 couples provided both copulatory and masturbatory ejaculates. Furthermore, those 35 couples did not provide equivalent numbers of ejaculate samples, with some couples producing many more ejaculates than others (e.g., copulatory

samples per couple ranged from 0-27). This heterogeneity in sample numbers across couples could have affected the results in unknown ways. In our sample of 34 couples, all couples provided equivalent numbers of copulatory samples and masturbatory samples. Moreover, small sample size is a recurrent limitation of psychological research investigating ejaculate quality (e.g., Baker & Bellis, 1989; Pook et al., 2005), perhaps due to difficulties recruiting participants outside a clinical setting. Nevertheless, future research should investigate the relationship between sperm competition risk and ejaculate quality using larger samples. Researchers could also investigate the influence of female partner menstrual cycle phase, which has been shown to be associated with changes in female attractiveness (e.g., Puts et al., 2013; Roberts et al., 2004; Welling & Orille, 2023) and may influence male sperm quality across sessions. Lastly, because the semen analysis machine used in the current research requires live sperm for analysis, it is possible that some participants claimed they delivered one or more ejaculates within an hour of producing it even though it may have been longer (which would have resulted in a sample with a greater proportion of aged or dead sperm that will have impacted several assessments of ejaculate quality). Future research might circumvent this limitation by having participants produce ejaculates in or near the lab at scheduled times and delivering them to the researcher immediately after they are produced.

In conclusion, we investigated the extent to which ejaculate quality is associated with sperm competition risk in the manner described by Baker and Bellis (1993, 1995). We did not find evidence of higher sperm numbers in ejaculates produced when couples reported spending less time together since their last copulation. However, we did observe greater sperm concentration when men perceived that they had higher numbers of potential sexual rivals (i.e., the female partner had more male friends and coworkers). Human sperm competition is an

under-investigated phenomenon that requires additional research, and we therefore hesitate to advance firm conclusions about ejaculate adjustment as a sperm competition tactic in humans. Nonetheless, the current research adds to the relatively limited literature on sperm competition in humans and highlights additional variables for consideration in future research.

Declarations

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Conflicts of interest

None of the authors have any conflicts of interest, financial or otherwise.

Availability of data

Electronic datasets (.sav files) have been provided as supplementary material.

Code availability

Not applicable

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Table 1. Descriptive statistics for target variables.

Variable	Mean	SD	Skew	Kurtosis
Sperm competition risk				
Time spent together (in hours)	45.43	43.20	14.51	23.02
Partner infidelity perceptions	1.65	1.12	6.38	6.16
Number of male rivals	7.98	9.15	12.30	33.34
Time spent with male rivals	3.15	1.60	0.86	-1.22
Ejaculate quality				
Sperm count (in millions)	57.47	55.48	12.30	20.12
Rapid prog. sperm concentration (millions/mL)	8.18	11.55	11.47	10.03
Overall sperm concentration (millions/mL)	77.18	60.07	6.52	3.16
Covariates				
Age (in years)	22.56	4.06	2.77	-0.06
Body mass index (BMI)	26.67	4.86	1.97	-0.53
Abstinence duration (in days)	2.82	1.33	15.12	30.39
Relationship length (in months)	25.46	25.96	7.67	14.19
Lifestyle factors	1.11	0.93	0.40	-0.75

Note: Partner infidelity perceptions were measured on a Likert scale from 1 – 7, with higher numbers representing greater infidelity perceptions; Time spent with male rivals was measured on a Likert scale from 1 – 10, with higher numbers indicating more time spent with rivals; For lifestyle factors, higher numbers correspond to more sperm-damaging habits.

Figure 1. This depicts the procedure participants used to prepare and deliver ejaculate samples to the lab in a manner that minimizes sperm death. For masturbatory samples, directions start at step four.

Step 1: Try not to spill any of the ejaculate out of the condom.

Step 2: Tie the condom closed using the black plastic twist tie.

Step 3. With the condom securely closed, place the condom into the specimen container.

Step 4. Tightly screw the top of the specimen container closed.

Step 5. Place the specimen container into the specimen collection bag.

Step 6. Tightly seal the specimen collection bag closed.

Step 7. Tightly wrap the specimen collection bag with the aluminum foil.

Step 8. Place everything into the brown bag.

Step 9. Transport the specimen either under the armpit or between the legs if driving while en route to the lab.